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THE CAUSE OF SOUND SPEED PROFILE DIFFERENCES BETWEEN ICAPS AND --ETC(U)
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Prepared for
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NSTL Station, Mississippi

Prepared under
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THE CAUSE OF SOUND SPEED PROFILE DIFFERENCES BETWEEN ICAPS AND SIMAS

FINAL REPORT
Volume I of II
May 1, 1980

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FOREWORD

This document is a Technical Task Report prepared under Contract Number N00014-79C-0676 for the Naval Ocean Research and Development Activity (NORDA), NSTL Station, Mississippi. It discusses the cause of noted differences in sound speed profiles generated by two Acoustic Performance Prediction (APP) systems, the Integrated Command Antisubmarine Warfare Prediction System (ICAPS) and the Sonar In-situ Mode Assessment System (SIMAS). This report is bound in two volumes with the technical discussion contained in Volume 1 and the extensive data listings, test cases and program documentation contained in Volume 2. Specifically, this work was performed for NORDA Code 530, the Ocean Programs Office, to further support the resolution of technical issues related to formulating a common APP environmental data base.

Ocean Data Systems, Inc., acknowledges Mr. Eigoro Hashimoto, NORDA Code 321, for his technical management of this task and for providing supportive information which led to the successful completion of this preliminary investigation. Cooperation of the individuals who provided the data, program documentation, and consultation assistance necessary to complete this effort is greatly appreciated. Those individuals are as follows:

Mr. George Brown, NUSC/NL Code 3351
Mr. Burley Brunson, NORDA Code 321
Mr. Doug Gordon, NAVOCEANO Code 9200
Dr. Paul Moersdorf, NAVOCEANO Code 9200
Mr. Eugene Podeszwa, NUSC/NL Code 3351

Finally, Ocean Data Systems is indebted to LCDR Al Galus, Manager Special Projects (Model Evaluation), Ocean Programs Office, NORDA Code 530, for his enthusiastic sponsorship of this work.

ABSTRACT

This ~~is a~~ Technical Task Report which discusses the cause of environmentally significant differences in sound speed profiles generated by ICAPS and SIMAS for eight ocean sites. The sites used for this investigation were selected from the identical sites for which profile comparisons were made and differences noted in the FY-79 APP Task II Report of 28 September 1979 by NORDA Code 321. In order to study the performance of the ICAPS and SIMAS profile generation algorithms, both of which take advantage of on-scene bathythermograph (BT) data, each computer code was documented and a version of each was coded and installed on the CDC 6600 for test purposes.

These CDC versions were installed without the associated historical data bases and with provision to accept the historical data as a user input. Each version was tested to insure that they operate the same as they do on their respective computer installations. This provided the capability to isolate differences caused by the algorithms from differences caused by the data used as input to the algorithms. The CDC capability also provided for a rapid turnaround of computer runs without necessitating time consuming NORDA, NAVOCEANO, and NUSC data preparation and exchanges.

The cause of noted differences were found to fall into four interrelated categories. First, the merge algorithms used by each system are based on different philosophies and those philosophies are reflected in the respective codes. Second, the method of selecting (depth, temperature) pairs from a recorded BT trace is different and these methods result in different definitions of the same BT as seen by the merge algorithm. Third, the historical profiles and the method of determining a representative historical profile for a given location and time are different. Fourth, the definition and usage of salinity in the development of the resultant sound speed profiles are different. A final category concerning human factors is discussed but no differences were found to be caused by human errors in data preparation. However, differences in data and capabilities understood to be implemented but not actually implemented as documented are identified.

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Section 1.0

INTRODUCTION

1.1 Background

In late FY-79, NORDA Code 530 was tasked by the APP program, managed by NAVSEA 06H4, to define a common environmental data base which would support the needs of the fleet platforms designated to receive the APP package. This task resulted in the completion of Reference (1)* in early FY-80 which consists of recommendations regarding the content and construction of the APP data base. Concurrent with this task, a supporting "quick look" study was conducted by NORDA 321 which compared sound speed profiles generated by ICAPS and SIMAS and reported on noted differences in (2).

The recommendations made in (1) and the resulting profile differences noted in (2) were presented to the APP sponsor during a meeting of program participants at NAVSEA on 21 February 1980. During this meeting a decision was made to ultimately prepare a common data base. However, several technical issues were raised as regards parameter sets, merge processes, appropriate data sources, and data usage. By direction received at that meeting, these issues were to be addressed by designated participants as soon as possible.

1.2 Scope

This document addresses the problem of determining the cause of profile differences noted in (2). Because of the compressed time schedule, it must be considered only a preliminary investigation of a restricted number of cases. The substantive background technical information contained herein provides valuable insight into determining the effects of combining BT data with historical environmental data as implemented in ICAPS and SIMAS.

*Hereafter references will be referred to by number only.

Subsequent sections discuss the technical approach used in this preliminary investigation and the detailed results for eight ocean sites selected from those used in (2). This discussion is based on a thorough analysis of available documentation and the source code of the respective algorithms as well as a detailed examination of the actual data used to generate the respective profiles. Volume 2 of this report contains the appendices which are provided for reference purposes. The appendices A, B, and C document the specific input data used in this investigation and the test results from computer runs made to isolate the cause of profile differences. Documentation prepared for the ICAPS and SIMAS profile generation methodologies and the implementation of these codes for test purposes is contained in Appendix D.

Although sensitive to the needs of the wide variety of fleet platforms receiving the APP package, this document does not address issues related to specifically what parameters are to be stored in a common data base, their resolution, accuracy and definition. These issues are better treated by further independent technical evaluation studies when due time may be given to provide sound technical recommendations. It does address the computer processing necessary to provide a quick and easy means to perform further ICAPS and SIMAS comparisons and analysis as necessary.

1.3 Objective

The established objective of this task was to determine the cause of differences between ICAPS and SIMAS generated profiles noted in (2). The sound speed profiles were generated using BT data at the eight ocean sites identified as follows:

F1C, F1F, A1F, F2A
F2E, A2E, F2H, A3A

where the first letter of each identifies February (F) or August (A) and the subsequent (number, letter) pair identifies the site location.

A prerequisite to adequately accomplishing this objective was to provide the capability to examine the parameter (temperature, salinity, depth, sound speed) and coded algorithm dependencies of the ICAPS and SIMAS profile generation processes. This capability was to be implemented so that the parameter and algorithm dependencies could be isolated and quantitatively examined. The implementation was to provide a side-by-side execution of the ICAPS and SIMAS profile generation algorithms on the CDC 6600 located at the Naval Ship Research and Development Center (NSRDC).

1.4 Project References

1. The APP Data Base — Recommendations for its Contents and Construction. Garon, H. M., Science Applications, Inc., McLean, Virginia, Task Report, (no date).

2. Comparison of the ICAPS and SIMAS Historical Environmental Data Base, Hashimoto, E., NORDA Code 321, FY-79 APP Task II Report, 28 September 1979.

3. The APP Data Base: Implementation Design and Impact (Draft), Locklin, J., Ocean Data Systems, Inc., Report for NORDA Code 530, 21 November 1979.

4. A Functional Description of the Sonar In-Situ Mode Assessment System (SIMAS) (U), Brown, G., Naval Underwater Systems Center, New London, Conn., NUSC TM 781058, 16 February 1978 (CONFIDENTIAL).

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6. The ICAPS Water Mass History File, Fisher, A. Jr. Naval Oceanographic Office, NSTL Station, Mississippi, NOO RP-19, May 1978.

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8. Description of ICAPS Environmental Data Structure, Lever, J., Naval Oceanographic Office, NSTL Station, Mississippi, Technical Note TN 3700-82-79, March 1979.

9. Definition of APP Informational Requirements to Support CV and VP Aircraft, Including TFCC and FCC Platforms, U.S. Naval Oceanographic Office, Washington, D.C., Technical Note TN 3700-017-77, May 1977 (CONFIDENTIAL).

10. A Survey of Marine Environmental/Acoustic Data Banks and Basic Acoustic Models with Potential Application to the Acoustic Performance Prediction (APP) Program, Etter, P., Flum, R., ASW Systems Project Office, Washington, D.C., ASWR 78-117, September 1978.

Section 2.0

TECHNICAL APPROACH

2.1 General Approach

This investigation into causes of significant differences between sound speed profiles generated by ICAPS and SIMAS has been organized into three areas:

- Definition and verification of inputs
- Isolation of differences by cause
- Preparation of results

An effective factor in performing this study was the generation and use of CDC computer versions of the ICAPS and SIMAS methodologies. A thorough study of available documentation along with the development of the CDC versions yielded insights into the respective ICAPS and SIMAS algorithms. The CDC versions provided the capability to address the three areas of this investigation without necessitating time consuming NORDA, NAVOCEANO and NUSC data preparation and exchanges. Furthermore, they enabled the usage of uniform inputs to both versions. In particular, the input of identical historical profile data into both ICAPS and SIMAS was necessary to isolate differences caused by the historical data from differences caused by either the merge or BT data.

Each CDC version was installed without the associated historical data base and retrieval algorithms, but were provisioned to accept historical as well as BT data as user inputs and perform the merge as each was originally designed. Once tested to insure that they produced equivalent results as they do on their respective computer installations, analyses were then performed in each of the three areas. Documentation was then organized to discuss the respective methodologies and to present the results along with all relevant data.

2.2 Definition and Verification of Input Data

The control profiles were selected from those in which differences were noted in (2). Human factor effects become identifiable by accurately reconstructing the input data. NAVOCEANO provided listings of the BT data used for ICAPS. The remaining listings of ICAPS data and SIMAS data were provided by NORDA 321. The ICAPS and SIMAS CDC versions were used to correlate the input data with the generated SSP's. This verification was required because the digital inputs were not documented in (2). Additionally, this provided a certifiable control on all subsequent parameter and coding sensitivity investigations as well as a demonstrated verification of the CDC versions.

2.3 Isolation of Difference Category

Only after human factor effects were eliminated was it possible to proceed with the identification and isolation of other causes. There are four categories that have the potential to cause differences between the control profiles produced by ICAPS and SIMAS. These categories are:

- Merge algorithm
- Historical sound speed profiles
- Bathythermograph (BT) profile resolution
- Salinity variation

The determination of which factor caused the differences is complicated by the fact that more than one factor may contribute to the differences. Thus it was necessary, in effect, to hold three factors constant while the resultant effects of the fourth factor were examined. For example, to examine the effects of the merge algorithms alone, it was necessary to provide both ICAPS and SIMAS with completely identical BT profiles and historical profiles including properly treated salinity values. Similarly, to examine the effects of the BT profile alone, it was necessary to provide ICAPS with varying BT profiles keeping the historical profiles the same, and likewise for SIMAS.

While this approach is somewhat tedious, it does provide a conclusive evaluation of the magnitude of difference caused by the varying factor. As much as time and tenacity permitted, only some of the differences were tabulated. The preliminary parameters examined were layer depth, surface sound speed and salinity, as well as sound speeds at depth where significant differences may be.

Subsequent discussion provides some insight into the general nature of each category and how differences in the ICAPS and SIMAS methodologies may be noted when examining the output profiles. This information was based on a thorough analysis of the respective codes and a detailed examination of the data inputs and outputs discussed in (2).

2.3.1 Merge Algorithm

The merge algorithm for each system produces an SSP having unique characteristics when compared with the associated historical SSP. This becomes clear as one realizes that the design philosophies are distinct from one another. *Consequently, differences in the mathematical algorithms* are reflected in recognizable features in the generated SSP. Detailed descriptions of the ICAPS and SIMAS methodologies are contained in Appendix D. A comparative chart is shown in Appendix D to illustrate ICAPS and SIMAS features. The following subparagraphs briefly discuss the design differences and point out characteristics to be expected.

2.3.1.1 ICAPS Merge

ICAPS is a merge methodology that assumes the BT data to be the best current information upon which to define the SSP. In concept, the historical environmental data (depth, temperature, salinity) is the most reasonable available information to define the deep region of the SSP and to provide salinities as an estimate for the near surface salinities. The process is a mathematical merge (Appendix D, enclosure 5) that merges the historical temperature profile below the deepest BT depth into the BT temperature profile. This can be observed by

overlaying a generated SSP with the corresponding historical SSP. The bottom of the generated profile will be similar (usually identical) to the historical SSP and, progressing toward the surface, will appear to stretch and bend away from the historical SSP toward the bottom of the estimated BT SSP.

2.3.1.2 SIMAS Merge

The SIMAS methodology differs from ICAPS in that the historical SSP is of prime importance. First, a near-surface SSP is generated from the BT temperature profile using a constant near-surface salinity value. A near-surface salinity value is specified with each historical SSP. Whenever this near-surface SSP and the historical SSP are within 9 ft/sec at 1000 ft, the SIMAS generated SSP is the near-surface SSP shifted by the sound speed difference at 1000 ft and extended by the historical profile points that are below the deepest BT depth. This can produce a profile characteristic that may appear discontinuous at the deepest BT depth when the shape of the BT below 1000 ft is not well matched with the historical profile. When the near-surface SSP and the historical SSP are not within 9 ft/sec* at 1000 ft, an adjustment algorithm generates an SSP from the historical profile with a near-surface revision. This revision depends upon the layer depths for the BT near-surface SSP and the historical SSP, and can cause differences in the near-surface profile structure, (e.g. the historical surface velocity can be incremented by 6 or 12 ft/sec, or an artificial point can be introduced at a depth of 1 foot with a sound speed of the historical surface sound speed plus 0.01 ft/sec).

2.3.2 Historical Profiles

The historical profiles used by ICAPS and SIMAS are extracted from data bases. These ICAPS and SIMAS data bases were developed from differing observed data sets by differing analysis methods and for differing spatial and temporal resolves. This leads to a different description of the same ocean.

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*Note: The SIMAS operator has the option to enter a new BT rather than continuing with the adjustment algorithm.

Both data bases describe the vertical variation of temperature and salinity (ICAPS), or sound speed (SIMAS) which approximate what historically has occurred in the real ocean. This description is organized by differing spacial provinces whose geographic boundaries are fixed (i.e. watermass or homogenous ocean areas) and by differing temporal provinces (i.e. month or season). While ICAPS allows the profile to vary within the province (i.e. up to 5 water masses may be represented), SIMAS provides for only one profile with an operator option to select a different profile. Furthermore each data base was implemented to support the specific needs of the different profile generation processes.

Consequently, the historical profiles extracted from these data bases may significantly differ at a given site. This difference is directly reflected in the resultant SSPs at depths deeper than those depths influenced by the BT.

2.3.3 BT Profile Resolution

The near-surface region of the generated profile is derived from the BT temperature profile usually provided by a Sippican SXBT recorder or equivalent. Consequently, the number of points defining the BT profile can affect the resulting near-surface region. ICAPS defines a BT by selecting flecture points from the BT profile, while SIMAS selects flecture points from straight line fits to the profile. This can produce differences between the ICAPS and SIMAS discrete representations of the BT profile and is reflected in the amount of detailed variations in the resultant sound speed profile. In addition, the merge algorithms differ in the treatment of the BT data. Therefore its definition is important to the automatic selection of the proper historical profile for ICAPS and the "accept/reject" criteria as well as the concatenation of the deep historical profile for SIMAS.

2.3.4 Salinity Variation

Both models require salinity in order to calculate the sound speed at a given depth for a specified temperature. ICAPS uses Wilson's equation, while Leroy's equation is used in SIMAS. For the same depth, temperature and salinity

values, the difference produced between the two equations, less than 1 ft/sec, is insignificant (Appendix D, enclosure 6). The models have different assumptions for assigning the near-surface salinities at the depths of the BT points. ICAPS performs linear interpolation from the historical salinity data while SIMAS uses a constant salinity associated with each historical SSP. Differences between constant and variable salinities as reflected in the resultant SSP may be noted when vertical salinity gradients are strong and produce significant vertical sound speed gradients.

2.4 Preparation of Results

The initial step was to generate a CDC version of each profile generation process so that uniform inputs to each could be used. To facilitate program usage, both versions can execute using the same input deck when the historical data is in the ICAPS format. Secondly, the ICAPS historical SSP's were regenerated. This provided water mass identification and accuracy correlation between results on different computer systems. Use of the same data in the SIMAS version documented insignificant differences produced by the Wilson and Leroy equations. Next, the BT data was used to regenerate the merge profiles for ICAPS. This identified which water mass was selected at each site which was represented by more than one water mass. Similarly, the BT data was used in the SIMAS version to validate the near-surface salinity used to produce the SSP's. Finally, cases were run to demonstrate the differences that occur due to differently derived BT data, and how ICAPS and SIMAS can differ even though the input history and BT data is unchanged.

Because of the compressed schedule associated with this investigation, no profile plots of the test results were prepared for visual inspection. These plots can conveniently be made available at a later date since the output profile data were formatted for proper interfacing with the plotting software.

Section 3.0

RESULTS

3.1 Reconstruction and Verification of Input Data

ICAPS and SIMAS generated SSP's resulting from respective use of BT profiles was tabulated in (2). This data and associated plots, reproduced in Appendices A6, A7 and A8, were the primary control profiles for the reconstruction of all necessary input data and the collected work sheets used in the preparation of the control profiles for (2) were used to reconstruct all input data. This input data was then verified to be the same since the control profiles were reproduced using the CDC Versions of ICAPS and SIMAS. Listings of this reconstructed input data for the eight sites is contained in Appendices A1 through A4.

Site identifiers used throughout this report are identical to those used in (2). Each site (i.e. test case) is identified by position and month. Table 1 shows the geographic locations of six sites, the two additional sites (cases) being provided by two months for locations 1F and 2E.

Important considerations to be referred to in subsequent discussion are definition of salinity, and definition of depth resolution for BT data prepared for input to ICAPS and SIMAS. Based on the reconstructed input data, Table 2 summarized the number of points defining input BT and historical profiles. It also provides the constant near-surface salinity values used for SIMAS. These salinity values were conveyed by phone from NORDA 321 and are based on information contained in the technical documentation of the SIMAS historical data files.

The data reproduced for ICAPS show acceptable machine accuracy. ICAPS environmental profiles are input to two decimal places. Comparison with the historical ICAPS profiles reveal depth agreements within .01 feet at the surface to 1 foot for deep bathymetry (18000 ft). The sound speeds showed a 0.3 ft/sec

N. Pacific
1C = 33.0°N, 172.5°W 1F = 42.0°N, 143.5°W
N. Atlantic Ocean
2A = 13.0°N, 38.0°W 2E = 47.5°N, 17.5°W 2H = 39.5°N, 68.5°W
Mediterranean Sea
3A = 37.5°N, 17.5°E

TABLE 1: GEOGRAPHIC LOCATIONS OF OCEAN SITES

Site	ICAPS		SIMAS		
	Historical Data	BT Data	Historical Data	BT Data	Near-surface Salinity
F1C	25	22	24	5	35
F1F	24	21	24	6	34
A1F	24	28	25	10	34
F2A	25	16	26	8	35.5
F2E	24	10	22	4	35.5
A2E	24	22	23	8	35.5
F2H	22	30	23	13	35
A3A	22	22	12	8	38

TABLE 2: NUMBER OF PROFILE POINTS AND SIMAS HISTORICAL NEAR-SURFACE SALINITIES

bias at all depths due to relative machine precision. For the ICAPS merged profiles, the CDC version produced a maximum of less than 1 ft/sec difference in sound speed, though the usual variation was $\pm$ 0.3 ft/sec. The use of the CDC version enabled the identification of the water masses selected for the ICAPS merges which was not obviously represented in (2). The reproduced control profiles for sites F1C, F1F, A1F, F2E, A2E and A3A are in Appendix B1, and those for sites F2A and F2H appear in Appendix B2.

The SIMAS historical data is reproduced with machine accuracy since this is direct SSP input. Appendix C1 contains the CDC version SIMAS generated control profiles, using the expected near-surface salinities shown in Table 2. Excellent agreement for depths (5 digits) and 0.1 ft/sec for sound speed was obtained except at sites F1F, A1F and F2A. Sites F1F and A1F showed a 4 ft/sec bias, and site F2A had a 2 ft/sec bias. These biases agree with the suspected differences in the constant salinity used from Table 2. Consequently, a rerun of these three cases for the near-surface salinity being 35 PPT (Appendix C2) produced the expected accuracy. An inquiry at NUSC confirmed that at some sites SIMAS historical near-surface salinities from the data base are assigned 35 PPT instead of the expected value provided in the historical data base documentation.

This detailed examination of all input data provided two significant results. First, the input data used for the preparation of (2) was accurately prepared and processed. Second, the CDC versions of the respective codes were adequately tested to insure that they produce, with insignificant machine accuracy effects, identical results as would be produced on their respective machine installations. This second result is paramount to using these codes for subsequent categorization of differences.

3.2 Isolation of Cause

In reviewing the subsequent results, the reader is cautioned as to what conclusions can be drawn from these limited test cases. First, the discussion and associated tables which refer to "SIMAS" and "ICAPS" refer specifically to the CDC versions of each profile generation code and not to the operational and

comprehensive "system" as implied by the last "S" in each acronym. Second, the quantitative values shown in the tables have been gleaned from the test run listings to summarize what may be viewed as "significant cause," and as such only refer to discrete profile related parameters. Third, no analysis has been performed to examine the realistic significance of the resulting vertical profile continuity which considers vertical gradients, profile shapes and the effect these have on underwater sound transmission. And finally, in the extremely short time available to perform this investigation, the test cases chosen must be considered only a small sample of the different oceanographic conditions which are present in the open ocean.

With these ideas in mind, the following discussion presents the differences discovered in each of the "significant cause" categories. For each category, test cases were constructed to isolate the cause of differences so that the discrete parameter quantitative differences could be tabulated. Section 3.3 provides a case by case discussion which explains some of the qualitative differences and relates these to particular "significant cause" categories where there were more than one cause acting on the composite profile comparisons.

3.2.1 Merge Algorithm

Profile differences caused by the different methods of merging is the most difficult to isolate because the merge methods use the BT and historical data with considerations for the parameters describing each. ICAPS operates on temperatures with subsequent salinity adjustments and SIMAS operates on sound speed. In order to make meaningful comparisons of merge processes alone, it was necessary to construct test cases using the control profile data such that the effects of these parameter considerations were minimized or, if possible, eliminated.

Holding the BT identical for ICAPS and SIMAS was trivial. Holding the historical profile identical was less trivial. This was accomplished by providing SIMAS with an ICAPS historical profile and then letting SIMAS compute its own historical SSP and also compute an average (constant) salinity for use with the

BT. This historical SSP then would be virtually identical to the one used for ICAPS. The average salinity was computed from the input historical salinity (surface to 500 meters) as a means to minimize the effects of a salinity value which was widely different from the input values.

Each of the eight cases were then executed. The specific data used for the historical inputs is listed in Appendix A1 and the BT data used is listed in Appendix A2. The resultant ICAPS profiles (B1) were then compared with the SIMAS profiles (C4) generated with the minimizing profile inputs. Differences noted in the layer depth and surface sound speeds are presented in Table 3. The cases where the SIMAS adjustment method was invoked (after rejection of the BT on the 1000 ft criteria) is identified. In these latter cases the resultant SSP is the historical SSP with a layer depth revision.

3.2.2 Historical Profiles

An intuitive understanding of the ICAPS and SIMAS processes obviates testing for differences in resulting SSP's caused by historical profiles alone. This is also readily shown by overlaying historical plots and merge plots from (2). Therefore no test cases were necessary to further identify causes in this category.

The profile plots in Appendix A7 for the control sites illustrate the difference between ICAPS and SIMAS historical profiles. The resultant SSP's shown in Appendix A8 reflect these same differences. Table 4 presents at a glance the depths above which the historical profiles differ when using the proper water mass selected for the ICAPS merge. When the BT is properly merged, the differences in the historical profiles above the deepest BT depth will not be reproduced in the resultant SSP. Only in the case where the default SIMAS adjustment is invoked, will these historical differences be reflected in the near-surface. In these latter cases, the near-surface differences are noted between a SIMAS modified historical BT SSP and an ICAPS merged BT.

	ICAPS		SIMAS	
Site	Layer Depth (ft)	Surface Sound Speed (ft/sec)	Layer Depth (ft)	Surface Sound Speed (ft/sec)
F1C	469.2	4964	469.2	4943*
F1F	357.6	4910	357.6	4881*
A1F	65.6	4936	65.6	4944
F2A	85.3	5046	85.3	5038*
F2E	3281.0	4903	1220.5	4909
A2E	72.2	4987	72.2	4982
F2H	420.0	4912	52.5	4798*
A3A	59.1	5059	59.1	5063

TABLE 3: ICAPS AND SIMAS LAYER DEPTHS AND SURFACE SOUND SPEEDS USING IDENTICAL BT AND HISTORICAL PROFILES (DIFFERENCES CAUSED BY MERGING)

*In these SIMAS generated results, the BT data is considered as probable errorred data, so that the generated profile is the historical profile with a layer depth revision.

Site	Depth (ft)
F1C	1200
F1F	2100
A1F	2400
F2A	6000
F2E	8200
A2E	8000
F2H	3000
A3A	1500

TABLE 4: DEPTHS ABOVE WHICH HISTORICAL PROFILES DIFFER

3.2.3 Bathythermograph (BT) Data

The definition of (depth, temperature) pairs describing the BT observation is directly reflected in the resultant SSP. This behavior is always present in ICAPS and only present in SIMAS when a successful merge is accomplished. Fleet operators of each system have been trained according to differing ICAPS and SIMAS "doctrine" to sample and record this BT definition prior to making operational computer runs. The test cases from (2) reflect this doctrine in the preparation of BT data and this resulted in a more detailed definition for ICAPS and a less detailed definition for SIMAS. "More detailed" implies more points on the BT trace were digitized and "less detailed" implies fewer points were digitized (Table 2).

The test cases used to demonstrate the effects of these differing BT definitions are listed in Appendices A2 and A3 for ICAPS and Appendices C1 and C3 for SIMAS. Keeping the historical profiles constant in the same manner as was done for the merge tests (Section 3.2.1) SIMAS and ICAPS were executed twice each, once with the detailed BT and once with the less detailed BT. Layer depths calculated by each BT definition were then compared for ICAPS and separately for SIMAS. These comparisons are shown in Tables 5 and 6, respectively.

The comparisons between ICAPS and SIMAS layer depth are not made since the method used by each is distinctly different and may yield drastically different values for calculated layer depths. How significant this difference is, may be determined by its use in the subsequently executed acoustic model. However, that significance is not addressed here. The occasionally drastic difference in calculated layer depth is cause by the respective methods. SIMAS chooses the depth below which the first negative sound speed is encountered when scanning the BT-SSP profile downward from the surface. ICAPS essentially selects the deepest sound speed maximum encountered scanning from the deepest BT depth toward the surface.

	LAYER DEPTH (ft) (L)		
Site	Detailed BT (I)	Less Detailed BT(S)	ΔL (I-S)
F1C	469.2	498.7	-29.5
F1F	357.6	357.6	0
A1F	65.6	98.4	-32.8
F2A	85.3	85.3	0
F2E	3281.0	3281.0	0
A2E	72.2	72.2	0
F2H	420.0	436.4	-16.4
A3A	59.1	59.1	0

TABLE 5: ICAPS LAYER DEPTH DIFFERENCES DUE TO BT PROFILE RESOLUTION

	LAYER DEPTH (ft) (L)		
Site	Detailed BT (I)	Less Detailed BT(S)	Δ L (I-S)
F1C	469.2*	498.7*	-29.5
F1F	305.1*	357.6*	-52.5
A1F	65.6*	98.4*	-33.2
F2A	85.3*	85.3*	0.0
F2E	1220.5	1617.5	-397.0
A2E	72.2	72.2	0.0
F2H	52.5*	114.8*	-62.3
A3A	59.1*	59.1*	0.0

TABLE 6: SIMAS LAYER DEPTH DIFFERENCES DUE TO BT PROFILE RESOLUTION

*In these SIMAS generated results, the BT data is considered as probable errorred data, so that the generated profile is the historical profile with a layer depth revision.

3.2.4 Salinity

Sound speed differences due to the usage of a constant versus a variable salinity would be confined primarily to the near-surface region of the SSP where the BT is used to replace the historical data. The tests to examine these differences therefore must use identical BT profiles and historical profiles with the salinities modifiable from constant to varying in the near-surface region. These resulting differences can then be compared independent of the merge process only after the sound speed is calculated and prior to any profile shifting which may occur in the SIMAS merge. For these tests, the final adjustments of salinity by ICAPS to achieve stability were insignificant relative to effects on the final profile and therefore can be ignored for these comparisons.

An initial concern is the determination of what a change in salinity will cause in the computed sound speed. Analysis of the Wilson and Leroy equations shows in the near surface region (down to 500 meters) that the approximation of change in sound speed with respect to salinity is given by:

$$\frac{dV}{dS} \simeq 1.398+(3.384)10^{-3}(S-35)-(1.1)10^{-2}T \qquad \text{(Wilson)}$$

$$\frac{dV}{dS} \simeq -0.01(T-18)+1.2 \qquad \text{(Leroy)}$$

where V = Sound speed (meters/sec)

S = Salinity (PPT)

T = Temperature (^{o}C).

Thus, for salinities 30-40 PPT and temperatures 0-30^{o}C

$\Delta V_{max} \simeq 1.4$ m/sec for $\Delta S = 1$PPT (i.e. 4.6 ft/sec)

So that, for $\Delta S \simeq 0.1$PPT, the velocity can change at most 0.14 m/sec (½ ft/sec).

A complete analysis of differences caused by salinity definition was hindered by the lack of suitable SIMAS output for all cases. The only point in the SIMAS execution where sound speeds are listed as calculated from the BT and a

constant salinity prior to the profile shift is when the BT fails the 1000 ft criteria and the adjustment algorithm is invoked. Therefore four test cases were constructed with the primary objective of illustrating the effect of using constant versus variable salinity independent of other factors. These cases were selected from those in which the SIMAS adjustment algorithm was invoked so that the proper comparisons could be made of the resulting sound speeds.

For each of the four test cases ICAPS and SIMAS were provided identical BT and historical (temperature and salinity) profiles. The SIMAS version was modified to initialize the historical sound speeds from the input temperature and salinity profiles and calculate an average near-surface salinity for use with the BT. This average salinity, in concept, is what would typically be shown in the SIMAS historical profile documentation. The ICAPS and SIMAS codes were then executed and the results are contained in Appendices B1 and C4 respectively. These differences are summarized in Table 7 for three depths in the near-surface BT region of each test case. The salinities shown in Table 7 are the constant average calculated value used by SIMAS and the variable salinity used by ICAPS to calculate the near surface sound speeds.

As a final note on these comparisons in Table 7, the average salinity used by SIMAS is different than those which would have been used from the SIMAS data base. This "data base" value is consistently 35 PPT for these sites from the Atlantic and Pacific Oceans. Using the estimated maximum sound speed difference of 4.6 ft/sec per salinity difference of 1 PPT, Table 8 shows the effective differences in sound speed which would be added to the ΔV column of Table 7 if 35 PPT were used. While these are not conclusive for all possible cases, they do illustrate the differences expected between average salinities versus constant 35 PPT values used by SIMAS.

3.3 Case by Case Discussion

Insights gained by studying the data and documentation as well as by developing the CDC versions is directed toward a subjective and qualitative evaluation of the causes of profile differences for the eight test cases. In

		SIMAS(S)		ICAPS(I)			
		Constant Salinity		Variable Salinity			
Site	Depth (ft)	Salinity (PPT)	Sound Speed (ft/sec)	Salinity (PPT)	Sound Speed (ft/sec)	ΔS (I-S)	ΔV (I-S)
F1C	0.0 830.1 1561.8	34.43	4964.8 4948.5 4911.4	34.41 34.33 34.07	4964.9 4948.3 4910.1	-0.02 -0.10 -0.36	0.1 -0.2 -1.3
F1F	0.0 767.8 1630.7	33.66	4910.7 4885.9 4852.9	33.40 33.98 33.97	4910.0 4887.6 4854.4	-0.26 0.32 0.31	-0.7 1.7 1.5
F2A	0.0 734.9 1492.9	36.34	5045.1 4948.6 4912.8	36.54 36.19 35.33	5046.1 4948.2 4908.9	0.20 -0.15 -1.01	1.0 -0.4 -3.9
F2H	0.0 807.1 1656.9	33.72	4917.2 4920.3 4873.4	32.41 34.76 34.91	4912.2 4924.8 4878.8	-1.31 1.04 1.19	-5.0 4.5 5.4

TABLE 7: CONSTANT VERSUS VARIABLE SALINITY EFFECTS ON SOUND SPEED PROFILES

Site	Salinity ($\bar{S}_{500}$) (Table 7) (PPT)	SIMAS Data Base Salinity(S) (PPT)	ΔS $\bar{S}_{500}$-S (PPT)	Max ΔV est. (ft/sec)
F1C	34.43	35.0	-.57	-2.62
F1F	33.66	35.0	-1.34	-6.16
F2A	36.34	35.0	1.34	6.16
F2H	33.72	35.0	-1.28	-5.89

TABLE 8: AVERAGE VERSUS 35 PPT
SALINITY EFFECTS ON SOUND SPEED

subsequent discussion, the historical and merged SSP comparisons in (2) are compared side-by-side and the resulting summary of significant cause by category is presented in Table 9 at the end of this section. To aid in this discussion, Figures 1 through 8 are provided at the end of this section for easy side-by-side visual comparison. These figures were reduced reproductions of the control profile plots in Appendix A and have been roughly annotated with working notes used in the preparation of this discussion. The solid lines represent ICAPS and the dotted lines represent SIMAS exactly as presented in (2).

SITE F1C (Figure 1)

The dominant cause of differences is distinctly the merge. The historical profiles agree below 1200 feet, yet the merge into the BT by ICAPS is recognized as bending away from the historical profile above 6400 feet towards the bottom of the BT at 1562 feet. The slight near-surface fluctuations in the ICAPS profile is due to the BT temperature variations with the salinity estimates and the slight effects of the BT data resolution. The resultant SIMAS profile was the adjusted historical profile with the modified layer depth taken from the BT.

SITE F1F (Figure 2)

The dominant cause of differences is distinctly the merge. The historical profiles agree with each other up to 2100 feet with slight differences above this depth. The ICAPS merged profile clearly shows the bending effect and slight effects due to the ICAPS BT data and near-surface salinity estimates while the SIMAS adjusted profile distinctly reflects strong historical influence.

SITE A1F (Figure 3)

The dominant cause of differences is again the merge. In this case SIMAS accepted the BT and in both systems the BT was well matched to the historical profiles. Furthermore, the ICAPS history showed vertical variations similar to those produced by the BT. The historical profiles are essentially identical below 2400 feet with the differences above 1499 feet due to the merge. SIMAS shows a

discontinuity at 1499 feet due to its profile shift which partially (up to 9 feet/second) explains the 13.6 feet/second difference at the surface. The rest of this latter difference (13.6-9=4.6) at the surface is due to slight BT data and salinity effects.

<u>SITE F2A</u> (Figure 4)

The dominant differences were caused by the merge with moderate contribution from the historical profile below 1493 feet. The BT was well matched to the historical ICAPS water mass 1 profile while SIMAS rejected the BT and adjusted the resultant profile. This adjusted SIMAS profile however does not appear to reflect the layer depth shown by the BT. At any rate, the primary differences above 1493 feet come from comparing ICAPS merged BT with SIMAS adjusted history.

<u>SITE F2E</u> (Figure 5)

The dominant cause of differences is clearly the historical profile. These major differences occur between the bottom of the BT at 1618 feet and 8200 feet below which the historical profiles become essentially identical. The fluctuation between 1000 feet and 1618 feet is caused by expected variations of salinity between the constant SIMAS value and the estimated ICAPS values since the BT shows (Appendix A2) no significant temperature fluctuations. Since SIMAS accepted the BT the basically parallel profile shapes above 1618 feet are due to the SIMAS profile shift to match history at 1000 feet. Only a minor discontinuity is shown immediately below 1618 feet due to this shift.

<u>SITE A2E</u> (Figure 6)

The differences are caused dominantly by the historical profiles and moderately by both the merge and the BT data. The differences in the historical profiles appear between 1500 and 8000 feet and are shown in the merged profiles. Since SIMAS accepted the BT the effect of the merge is indicated by the profile shift immediately below the deepest BT depth at 1358 feet. This

shift also explains the surface sound speed difference of 8.3 feet/second. The SIMAS BT data being smoothed does not contain the temperature fluctuations contained in the ICAPS BT data. This is reflected in the merged SSP's in the 400 to 1000 feet region. The divergence of the bottom of the ICAPS history from the SIMAS history is unexplained and is not reproducible using available reconstructed input data.

SITE F2H (Figure 7)

The dominant cause of differences is the merge with moderate contribution from historical profile differences. SIMAS rejected the BT and the resultant profile shows the strong influence of the historical profile while ICAPS reflects the near surface fluctuations caused by the BT. In spite of the historical profile differences, the ICAPS merge resulted in a profile whose shape more closely resembles the SIMAS history than the ICAPS history.

SITE A3A (Figure 8)

The dominant cause of differences was the merge. The slight near-surface fluctuations in the ICAPS SSP is due to the ICAPS BT temperatures while SIMAS rejected the BT but produced an adjusted profile which is the same as ICAPS in the first 75 feet. The SIMAS profile then reverts to SIMAS history below that depth. The difference seen at the bottom of the BT shows the historical ICAPS profile bending toward the BT at 1454 feet.

Site	Merge Algorithm	Historical Profile	Bathythermograph Data	Salinity Variation
F1C*	Dominant		Slight	
F1F*	Dominant		Slight	
A1F	Dominant		Slight	Slight
F2A*	Dominant	Moderate		
F2E	Moderate	Dominant		Slight
A2E	Moderate	Dominant	Moderate	
F2H*	Dominant	Moderate		
A3A*	Dominant			

TABLE 9: QUALITATIVE SIGNIFICANT CAUSE OF DIFFERENCES

* The SIMAS results considered the BT data to be as probable errorred data, so that the generated profile is the historical profile with a layer depth revision.

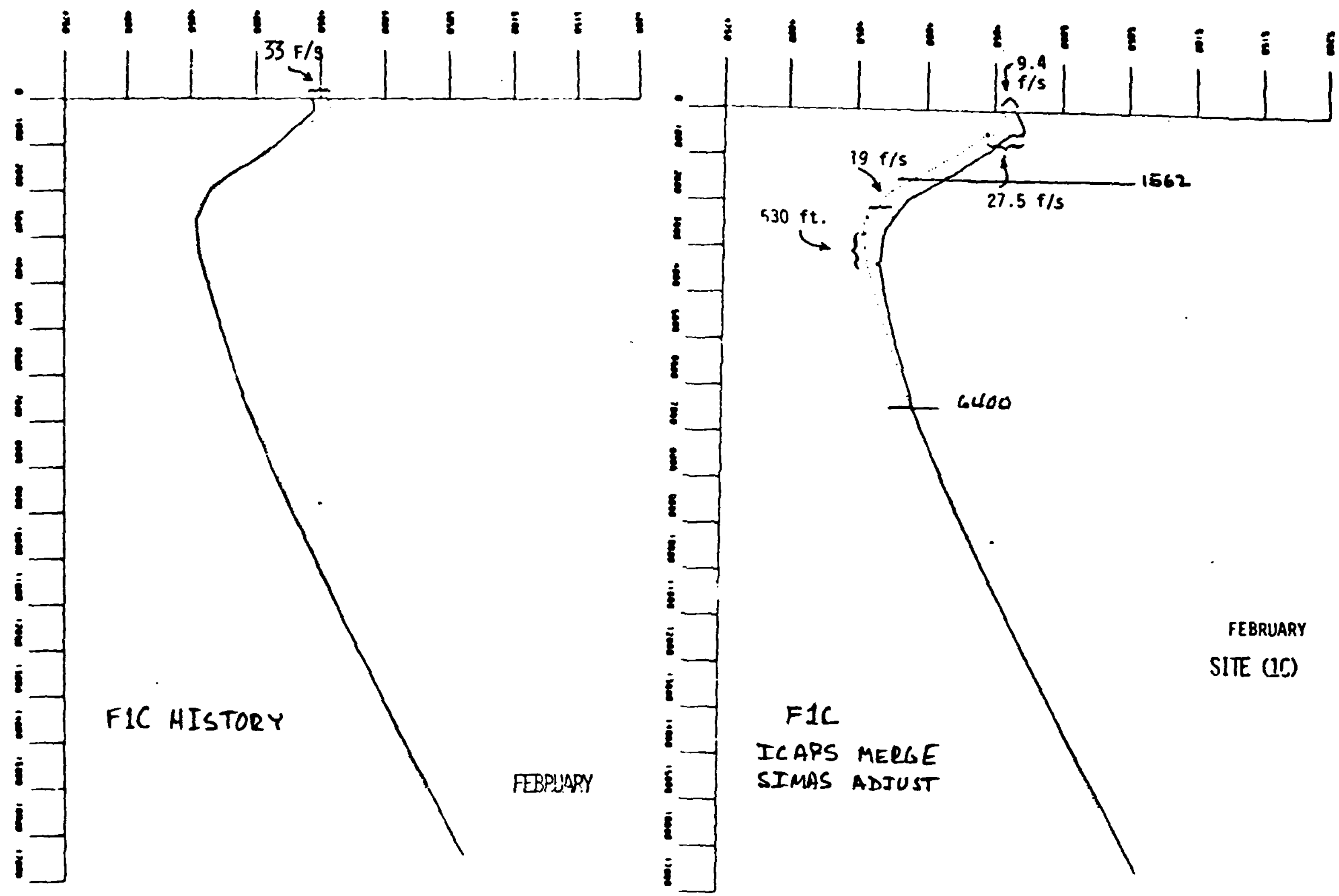


FIGURE 1: PROFILES FOR SITE F1C

FIGURE (6) (A7-2)

FIGURE 97 (A8-2)

108

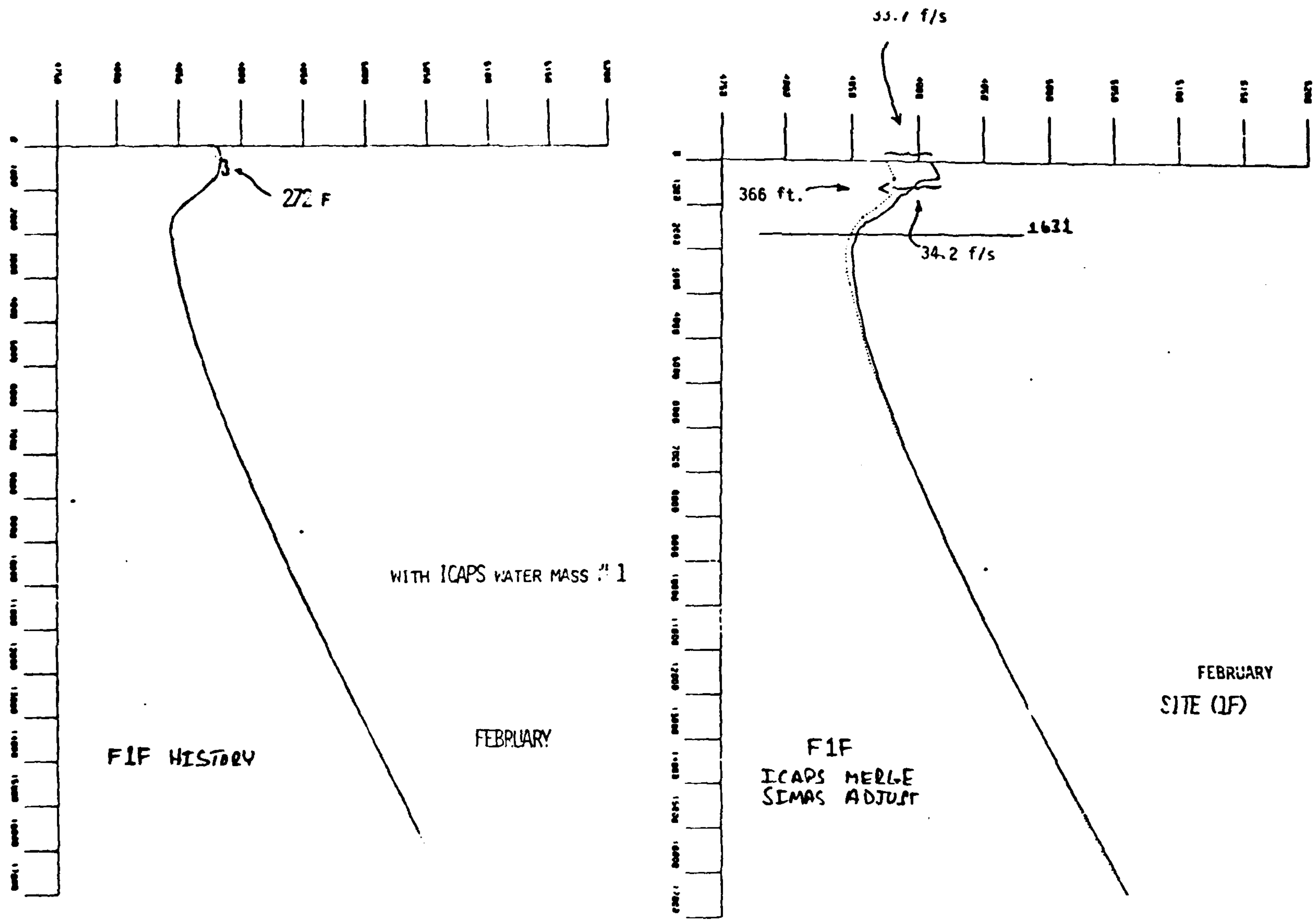


FIGURE 2: PROFILES FOR SITE F1F

FIGURE (14)
22 (A7-3)

FIGURE 99
(A8-3)
56

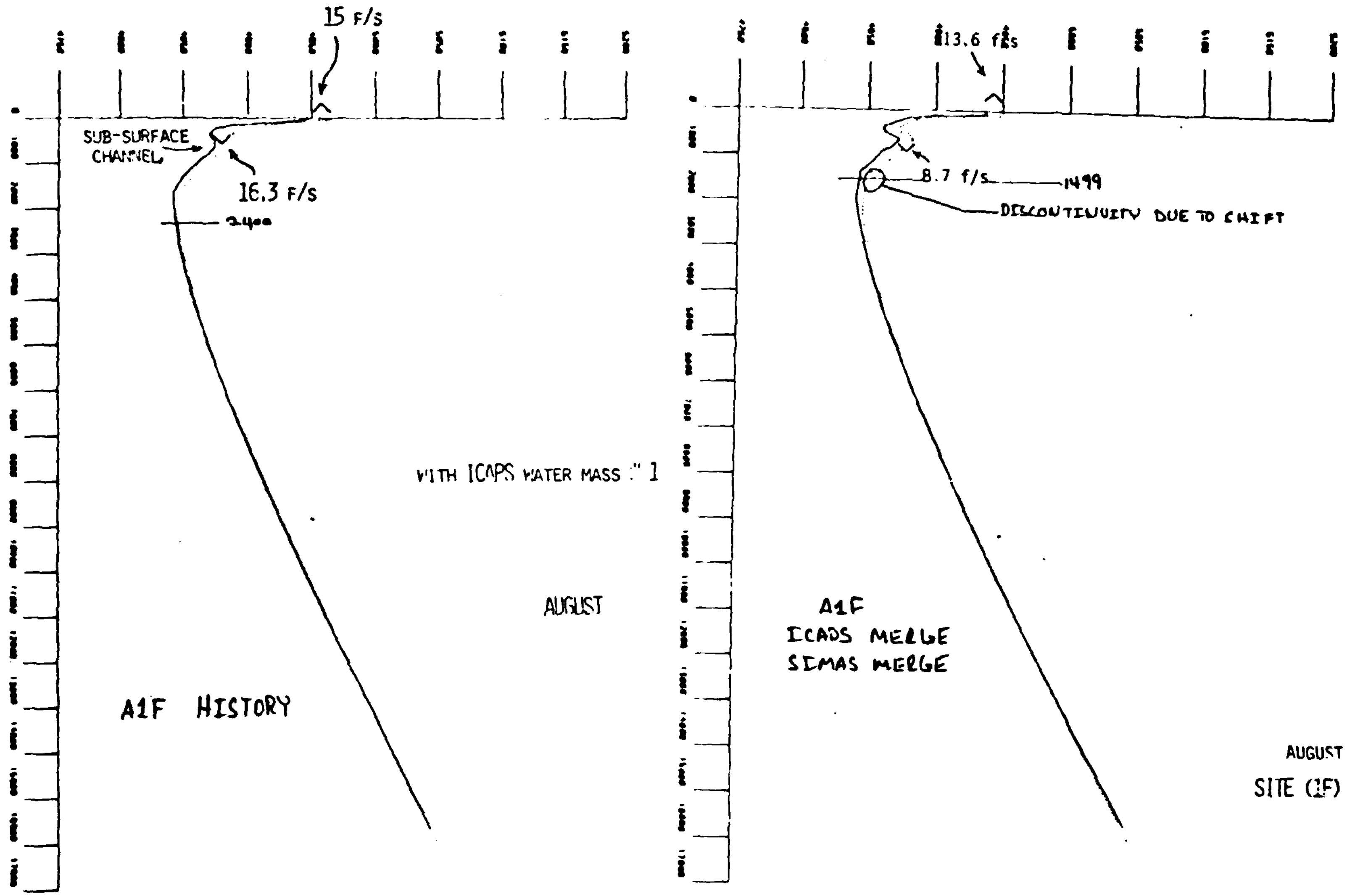
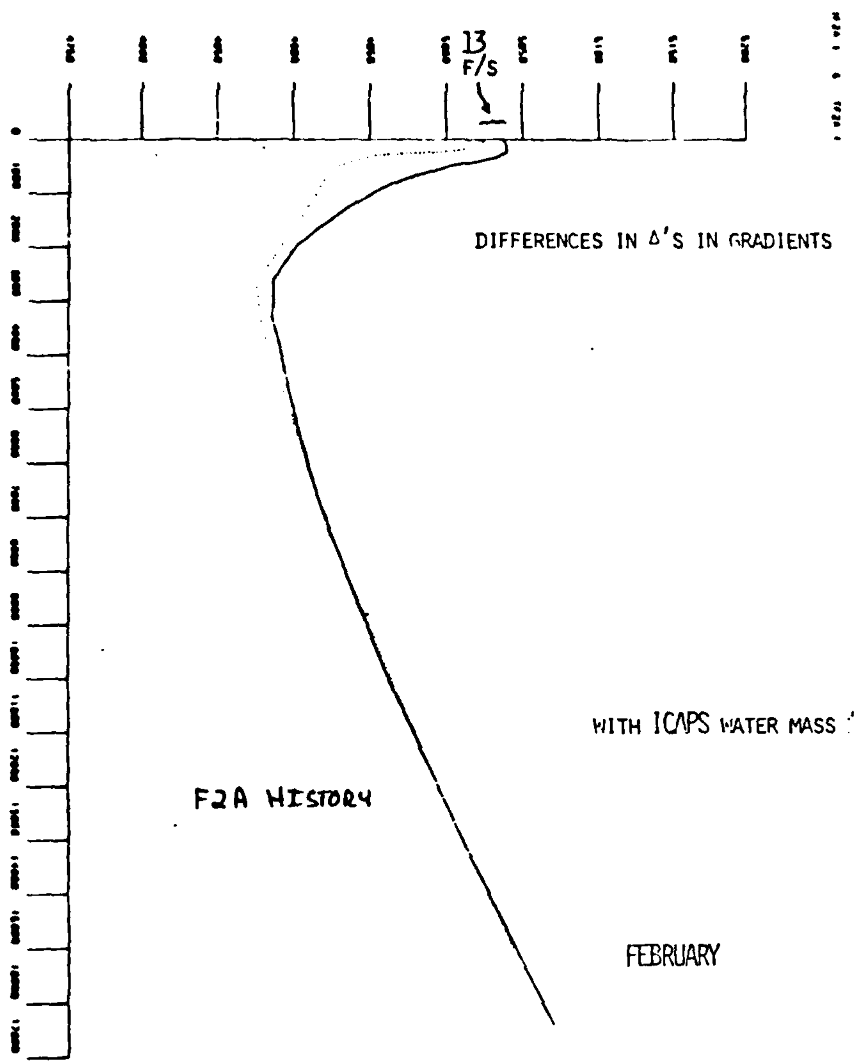


FIGURE 3: PROFILES FOR SITE A1F

FIGURE (49) 58 (A7-4)

FIGURE 111 121 (A8-4)



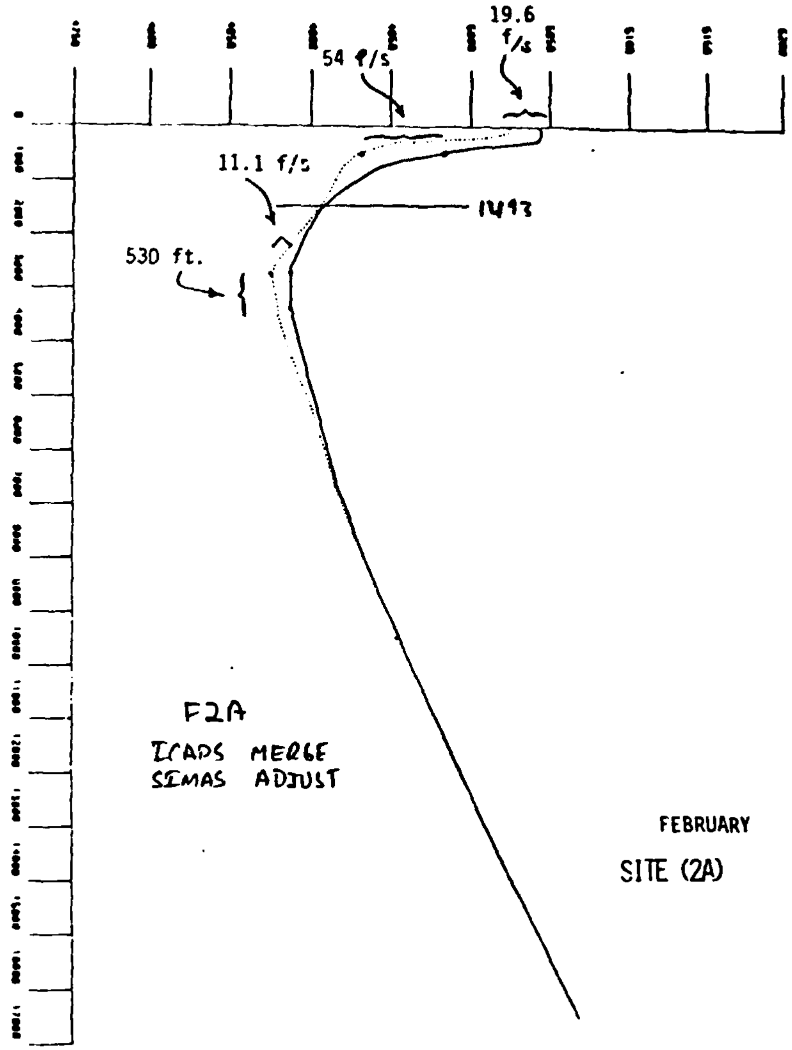


FIGURE 4: PROFILES FOR SITE F2A

FIGURE (16)
24 (A7-5)

FIGURE 100
(A8-5)
119

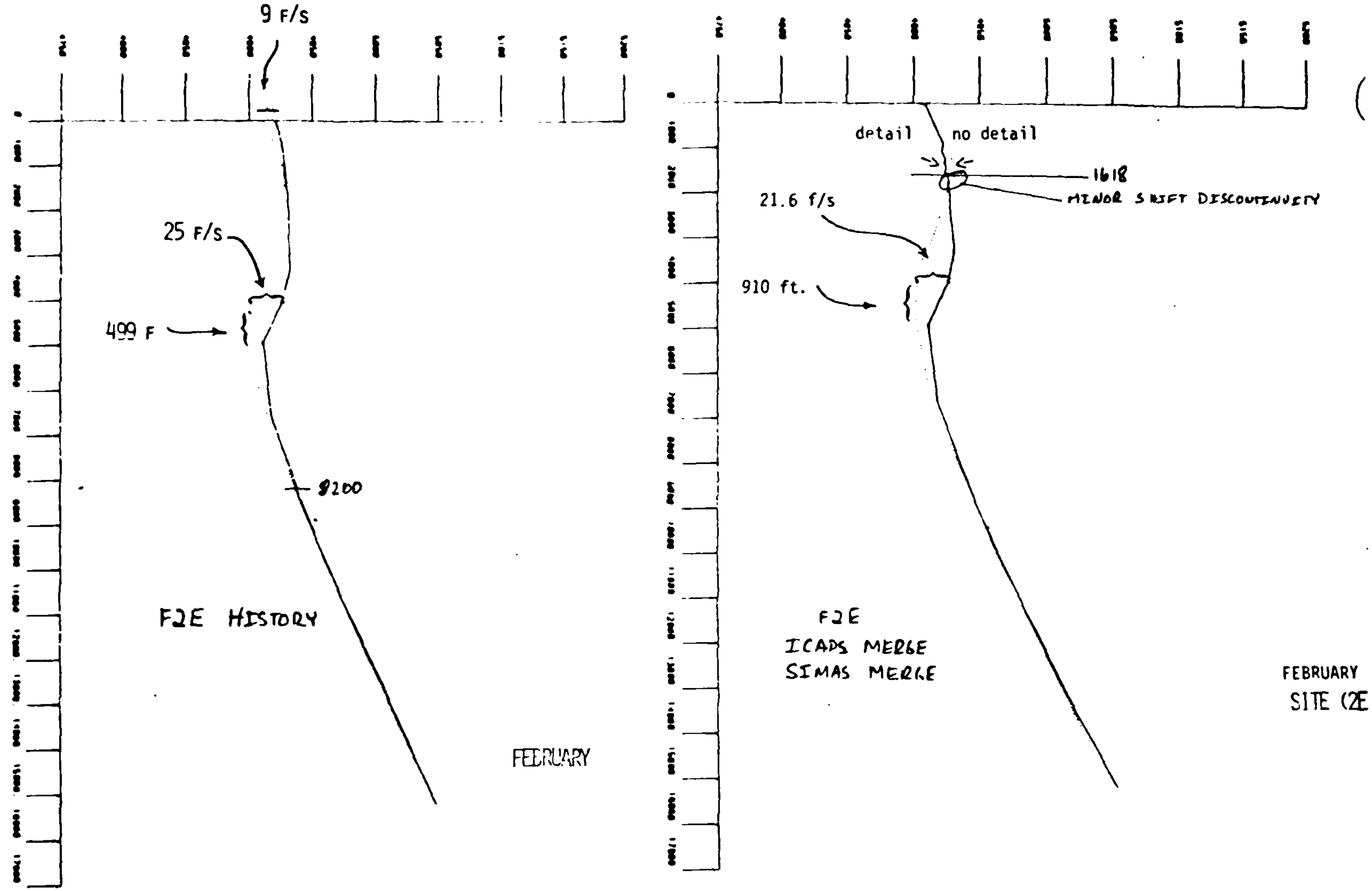


FIGURE 5: PROFILES FOR SITE F2E

FIGURE (23)
31 (A7-6)

FIGURE 104
(A8-6)
114

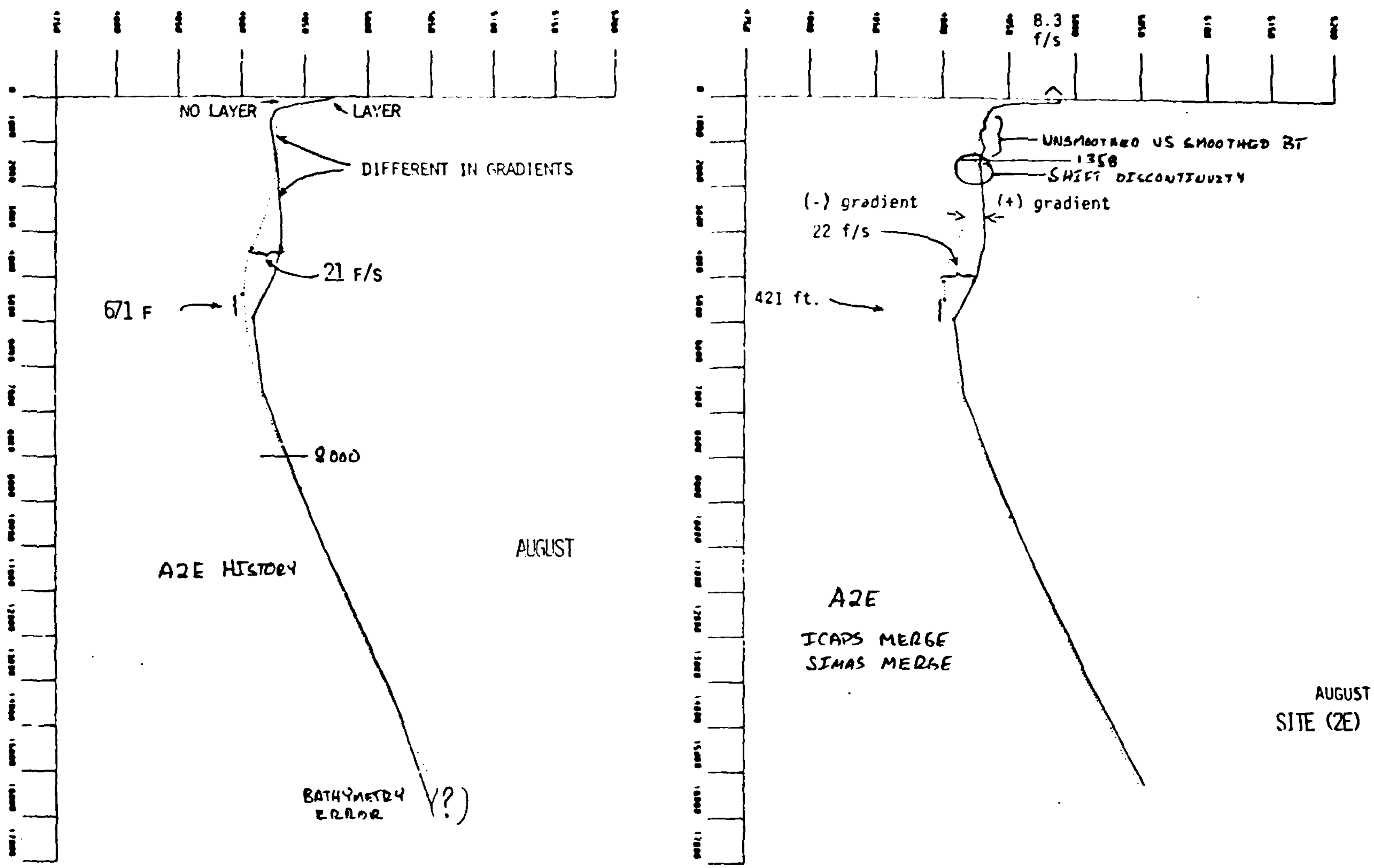


FIGURE 6: PROFILES FOR SITE A2E

FIGURE (58) (A7-7) 67

FIGURE 115 (A8-7) 125

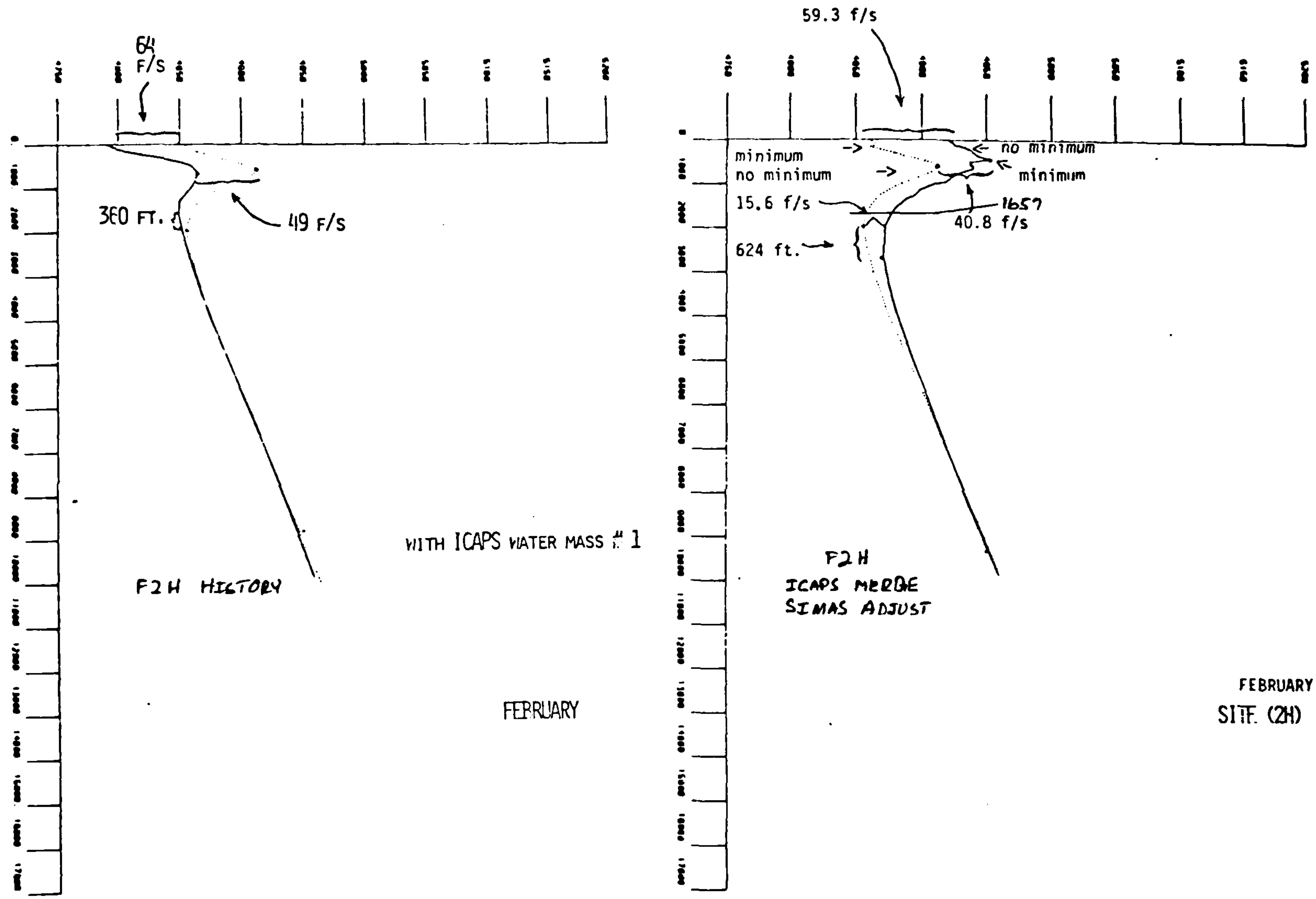


FIGURE 7: PROFILES FOR SITE F2H

FIGURE (28) (A7-8)

FIGURE 105 (A8-8)
115

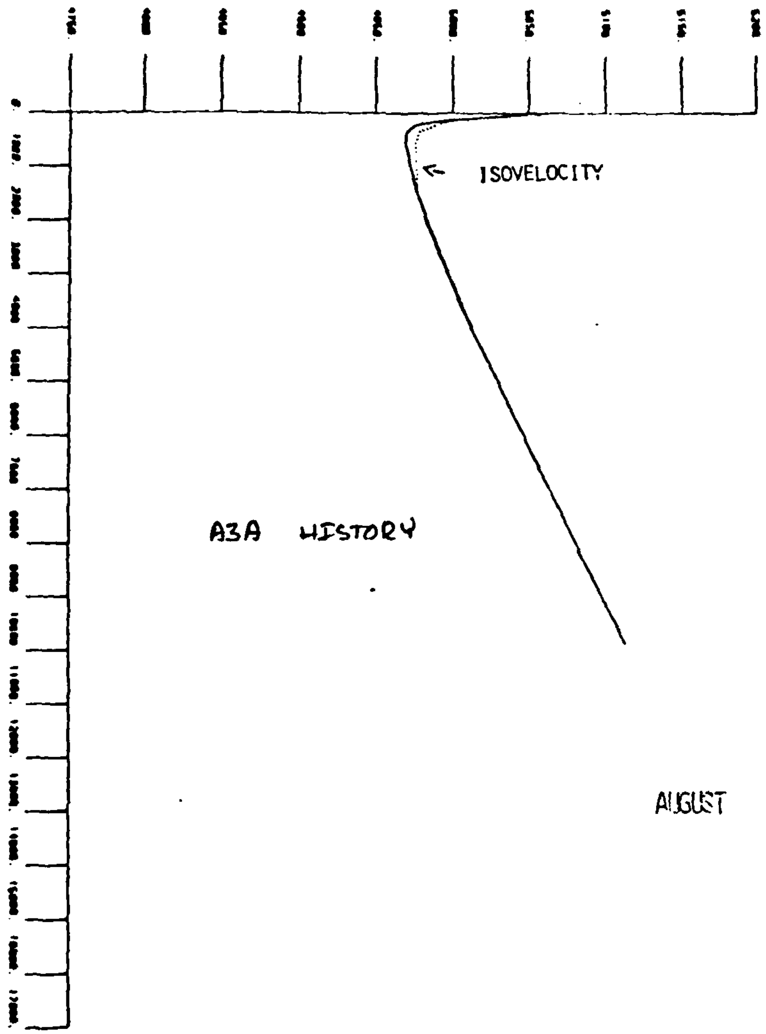


FIGURE (67)
76 (A7-9)

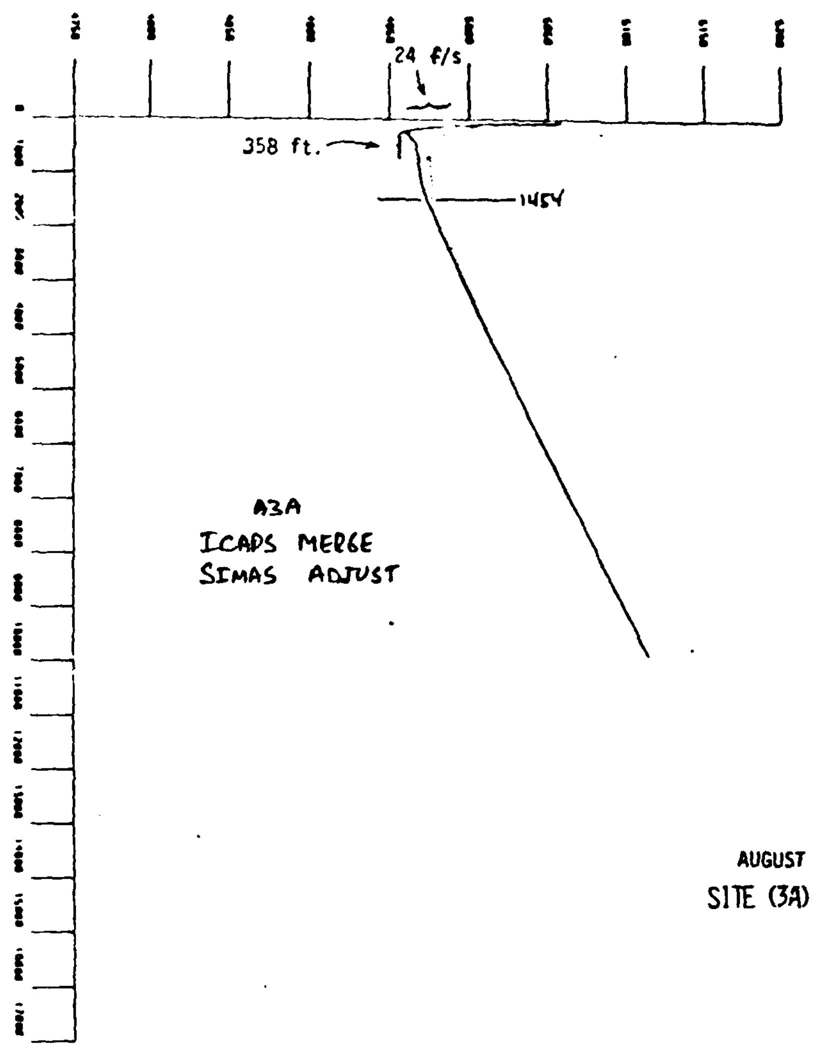


FIGURE 119
129 (A8-9)

FIGURE 8: PROFILES FOR SITE A3A

Section 4.0

CONCLUDING REMARKS

An overall APP objective is to provide uniformly high quality products to the Fleet. Two supporting and important considerations for accomplishing that objective are the provision for a uniformly high quality environmental data base and the usage of uniformly high quality procedures for defining the best possible description of the ocean environment upon which acoustic performance predictions depend. The results of this study meet the limited objective of determining differences in ICAPS and SIMAS which may ultimately cause different acoustic predictions. Additionally, the supporting documentation and concepts presented here provide accurate technical information which may be used to underpin future programmatic decisions, decisions directed toward achieving the overall APP objective.

Previous efforts have addressed these differences by identifying that they exist. This study has attempted to define specifically why they exist in eight cases. The predominant category which caused differences in resultant SSP's produced by ICAPS and SIMAS was the merge. The next most significant cause was the historical profile data extracted from the respective data bases. BT data and salinity variations were found to be less significant causes.

These conclusions are based only on the limited eight cases and are certainly not conclusive of other factors which may affect acoustic predictions. For example, even though salinity variation caused relatively insignificant differences for these cases, one cannot conclude that this will be the case in ocean areas where salinity gradients are known to exist. Furthermore, the question of how all these differences affect the critical acoustic predictions used by the Fleet and the tactical implication of these differences is yet quantitatively unanswered.

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